

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 09-167789

(43)Date of publication of application : 24.06.1997

(51)Int.Cl.

H01L 21/66
G01B 11/06
G01N 21/00
G01N 21/27
G01N 21/64
G01N 21/88
G01N 23/20
G01N 23/223

(21)Application number : 07-325928

(71)Applicant : TOSHIBA CORP

(22)Date of filing : 14.12.1995

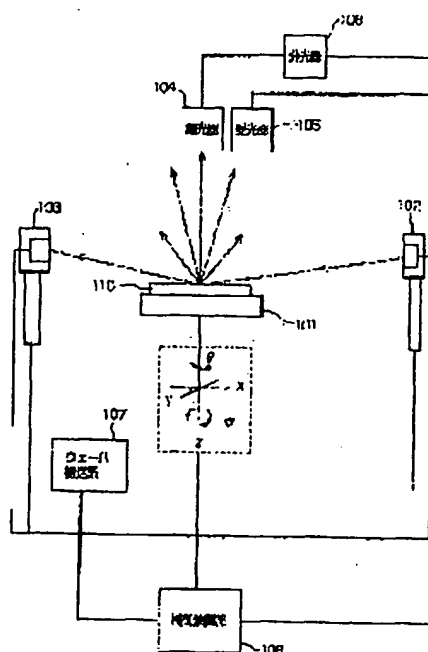
(72)Inventor : KAMAKURA TAKANOBU

(54) EVALUATION METHOD FOR SEMICONDUCTOR DEVICE

(57)Abstract:

PROBLEM TO BE SOLVED: To realize a highly reliable method for evaluating a semiconductor substrate.

SOLUTION: A wafer 110 to be evaluated is mounted on a stage 101 and the position and angle of wafer 110 are adjusted at a control processing section 108. The wafer 110 on the stage 101 is then irradiated sequentially or simultaneously with X-rays, argon laser light and YAG laser light from a light source section 102 and the reflected light or fluorescence is detected by means of a condenser 104 or a light receiving unit 105 in order to perform fluorescent X-ray analysis, locking curve measurement, PL inspection and detect inspection of the wafer 110. Respective characteristics measured through the inspection process are compared with the final pass/fail decision results for a semiconductor laser made of a wafer 110 passed through the inspection process and the evaluation criterion of wafer 10 is determined or corrected.



LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

CLAIMS

[Claim(s)]

[Claim 1] The evaluation method of the semiconductor substrate characterized by providing the following Substrate maintenance process in which the position and angle of the aforementioned semiconductor substrate which were laid in this installation base are adjusted by the controller after laying the semiconductor substrate for evaluating in an installation base By irradiating two or more kinds of evaluation light used for two or more kinds of evaluations sequential or simultaneous from two or more kinds of light sources at the aforementioned semiconductor substrate on the aforementioned installation base, and detecting the reflected light or the fluorescence at this time by two or more kinds of light sensitive cells, respectively Two or more aforementioned kinds of properties measured in the inspection process which measures two or more kinds of properties of the aforementioned semiconductor substrate, and this inspection process The error-criterion decision process which determines or corrects the error criterion of the aforementioned semiconductor substrate by comparing with the final good to the semiconductor device produced from the aforementioned semiconductor substrate which passed through this inspection process / poor judgment result

[Claim 2] The evaluation method of the semiconductor substrate according to claim 1 characterized by including either X line source, an argon laser or a YAG laser at least as the aforementioned light source used in the aforementioned inspection process.

[Claim 3] The evaluation method of the semiconductor substrate according to claim 1 characterized by including either the scintillation counter for diffraction X-ray detection, the detector for fluorescence X rays or the substage condenser for laser beams and a photo multiplier at least as the aforementioned light sensitive cell used in the aforementioned inspection process.

[Claim 4] The evaluation method of the semiconductor device according to claim 1 characterized by measurement including either X-ray fluorescence, rocking curve measurement, photoluminescence measurement or scattered-light observation for two or more aforementioned kinds of properties.

[Translation done.]

* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] this invention relates to the equipment and the method for carrying out non-destructing evaluation of the thickness of the thin film formed on the semiconductor substrate, composition, a luminescence property, the crystal defect, etc. at a detail more about the evaluation equipment and the evaluation method of a semiconductor substrate.

[0002]

[Description of the Prior Art] About an example of the evaluation method of the conventional semiconductor substrate, the case where the thin film grown epitaxially on the semiconductor substrate is evaluated is taken and explained to an example.

[0003] It is common to carry out the laminating of the dozens of layers super-thin film of 10nm of numbers from several nm in thickness by epitaxial growth with a heterojunction compound semiconductor epitaxial wafer with highly-efficient-izing of a device etc. In such a thin film, it is difficult to maintain the thickness of each class, composition, the concentration of doping, the steep nature of an interface, etc. with sufficient repeatability, and many properties of a thin film will be changed for every growth batch. For this reason, in a semiconductor manufacturing technology, after forming a thin film in a semiconductor substrate, while establishing a thin film evaluation process and sorting out the good/defect of a semiconductor substrate, it is necessary to correct the parameter of thin film deposition systems (MBE equipment or MOCVD system).

[0004] Drawing 9 is a flow chart which shows the procedure of the conventional evaluation method roughly.

[0005] As shown in drawing 9, by the conventional evaluation method, first, a thin film is grown epitaxially to all the semiconductor wafers of the same batch (S901), then the semiconductor wafer for evaluation is sorted out from these semiconductor wafers (S902). And the following evaluation examinations are performed one by one about the semiconductor wafer sorted out.

[0006] And this semiconductor wafer is set in film quality evaluation equipment, and film quality of an epitaxial growth phase is inspected (S903). In this film quality, after setting a semiconductor wafer to the wafer stage of an oblique light illumination unit, coating of the number of the particle of the whole semiconductor wafer surface is carried out using the surface contamination test equipment and the optical microscope which are called a particle counter.

[0007] Next, this semiconductor wafer is conveyed, it sets to the wafer stage of X diffraction equipment, and the rocking curve of an epitaxial growth phase is measured about arbitrary setting positions (S904). In this measurement, an X-ray is irradiated from X line source at an epitaxial growth phase, and the optical intensity of the diffracted light is measured by the scintillation counter. Thereby, composition of an epitaxial growth phase, thickness, etc. can be specified.

[0008] Then, this semiconductor wafer is conveyed, it sets to the wafer stage of PL (Photo Luminescence) evaluation equipment, and the luminescence intensity of photograph luminescence is measured about arbitrary setting positions (S905). According to measurement of this luminescence intensity, the luminescence wavelength of the semiconductor laser manufactured using this semiconductor wafer can be specified.

[0009] Then, based on the result of each of these properties (S903-S905), the quality of the thin film quality of the semiconductor wafer of the batch concerned is judged (S906). As for this quality evaluation, according to this invention person's etc. examination, it is desirable to examine the result of each above-mentioned property separately, not to judge it, but to associate these properties mutually and to judge them. For example, even if the property (namely, number of particle) measured with the oblique light illumination unit was a "defect", when the property measured with X diffraction equipment or PL evaluation equipment is very good, it may make quality evaluation "good." It is because the yield is made to fall more than required and it becomes the cause of manufacturing-cost elevation, when any one kind of the inspection item becomes a "defect" and it always judges quality evaluation to be a "defect." Here, the mutual relevance of each property changes with the kind of semiconductor device produced using the semiconductor wafer concerned, degrees of integration, uses, etc., and is experientially determined by comparing the measurement result of each above-mentioned property with the final good of a semiconductor device / poor judgment result etc.

[0010] And only when such quality evaluation is cleared, other semiconductor wafers of the batch concerned are thrown into the following manufacturing process.

[0011]

[Problem(s) to be Solved by the Invention] As mentioned above, it is common that the film quality evaluation of a semiconductor wafer estimates based on the measurement result about two or more kinds of properties. Thus, since different evaluation equipment for every parameter was conventionally used when two or more kinds of measurement was performed, the semiconductor wafer had to be transported for every measurement and it had to set to the wafer stage. For example, in the case of the evaluation method shown in drawing 9, it will be necessary to transport a semiconductor wafer in order of oblique light illumination unit -> X diffraction equipment -> PL evaluation equipment. For this reason, in the conventional evaluation method, in order to conduct inspection of two or more items about the same part of a semiconductor wafer front face, marking of the evaluation part of a semiconductor wafer needed to be carried out with the felt-tipped marker etc.

[0012] however, since marking by this felt-tipped marker etc. makes a semiconductor wafer pollute, and it is not nondestructive inspection namely,, it cannot throw into a subsequent manufacturing process the semiconductor wafer by which marking was carried out That is, by the conventional method, only the semiconductor wafer which did not pass through the above evaluation processes is thrown into a

subsequent manufacturing process. For this reason, when the defective of a semiconductor device occurs in a subsequent manufacturing process, the measurement result about the property of the semiconductor wafer used for manufacture of the defective is not left behind. [0013] On the other hand, in not performing marking, problems, like there is no repeatability in the precision of the position which evaluates arise.

[0014] Therefore, by the conventional evaluation method, it considered that the measurement result about the semiconductor wafer of the same batch as the semiconductor device judged to be a defective is the property of the semiconductor wafer used for manufacture of this defective, and was used for the analysis of the mutual relevance of each property. For this reason, mutual relevance about each property could not be analyzed strictly, and the reliability of the evaluation to the film quality of a semiconductor wafer was low.

[0015] Thus, a low case, since the semiconductor wafer which can be thrown into a manufacturing process may originally not only be judged to be a "defect", but the semiconductor wafer which should be made into a "defect" will originally be thrown into a manufacturing process, the reliability of the evaluation to the film quality of a semiconductor wafer also causes the fall of the yield in final evaluation of a semiconductor device. Therefore, in a low case, the reliability of the evaluation to film quality will become [the manufacturing cost of a semiconductor device] very large.

[0016] Moreover, since a transfer of a semiconductor wafer and a setup of an evaluation position would take a long time when transporting a semiconductor wafer for every measurement and setting to a wafer stage like the evaluation method shown in drawing 9, there was also a fault that the duration of an evaluation process will become long.

[0017] this invention is made in view of the fault of such conventional technology, and aims at offering the evaluation method of a reliable semiconductor substrate.

[0018]

[Means for Solving the Problem] Substrate maintenance process in which the position and angle of the aforementioned semiconductor substrate which were laid in this installation base are adjusted by the controller after laying the semiconductor substrate for the evaluation method of the semiconductor substrate concerning this invention evaluating in an installation base. Two or more kinds of evaluation light used for two or more kinds of evaluations is irradiated sequential or simultaneous through the same optical path at the aforementioned semiconductor substrate on the aforementioned installation base from two or more kinds of light sources. By detecting the reflected light or the fluorescence at this time by two or more kinds of light sensitive cells, respectively Two or more aforementioned kinds of properties measured in the inspection process which measures two or more kinds of properties of the aforementioned semiconductor substrate, and this inspection process By comparing with the final good to the semiconductor device produced from the aforementioned semiconductor substrate which passed through this inspection process / poor judgment result, it is characterized by having the error-criterion decision process which determines or changes the error criterion of the aforementioned semiconductor substrate.

[0019]

[Embodiments of the Invention] Hereafter, 1 operation gestalt of this invention is explained taking the case of the case where the semiconductor wafer used for manufacture of the transistor for RFs is evaluated.

[0020] Drawing 1 is the conceptual diagram showing the composition of the evaluation equipment used for this operation gestalt.

[0021] In this drawing, the wafer stage 101 holds the semiconductor wafer 110. The drive of movement to the direction of X, the direction of Y, and a Z direction, theta rotation, and phi rotation is possible for this wafer stage 101. Here, movement to the direction of X, the direction of Y, and a Z direction is controllable by the 1-micrometer step. Moreover, theta rotation can control phi rotation by the pitch of 0.001 degrees 0.0001 degrees.

[0022] The light source section 102 is equipped with copper or X line source (either an enclosure pipe or a rotating target is OK) of molybdenum, the argon laser (luminescence wavelength of 488nm), and the YAG laser (luminescence wavelength of 1.06 micrometers) (neither is illustrated). Furthermore, this light source section 102 is equipped with the mirror and analysing crystal (neither is illustrated) for drawing the evaluation light (namely, an X-ray and a laser beam) irradiated from each of these light sources on the same optical axis. Moreover, each light source of the light source section 102 can make the periphery top which makes the wafer stage 101 the center of rotation drive at the step of 0.0001 angle errors by control of the control operation part 108.

[0023] A scintillation counter 103 is used in order to receive the X-ray which irradiated from X line source of the light source section 102, and was reflected on semiconductor wafer 110 front face and to measure optical intensity. This scintillation counter 103 can make the periphery top which makes the wafer stage 101 the center of rotation drive at the step of 0.0001 angle errors by control of the control operation part 108 like the light source of the light source section 102.

[0024] The substage condenser 104 is arranged right above the wafer stage 101. Since luminescence of the photograph luminescence when irradiating the argon laser light of the light source section 102 is condensed to the semiconductor wafer 110 on the wafer stage 101, and since the scattered light when irradiating the YAG-laser light of the light source section 102 is condensed, this substage condenser 104 is used.

[0025] The electric eye 105 as well as a substage condenser 104 is arranged right above the wafer stage 101. This electric eye 105 exchanges a position for a substage condenser 104 mutually, and it is held by the drive system which is not illustrated so that it can move onto the core of the semiconductor wafer 110 on the wafer stage 101. Moreover, SSD (Solid State Detector) which is the detector of fluorescence X rays as this electric eye 105 is used, and the fluorescence X rays generated when an X-ray is irradiated at the semiconductor wafer 110 on the wafer stage 101 are received.

[0026] The spectroscope 106 is connected with the output terminal of a substage condenser 104 by the optical fiber. And the wavelength distribution of condensing intensity is measured using the lightwave signal inputted from the substage condenser 104. The measured wavelength distribution is outputted from the signal output terminal (not shown) of a spectroscope 106.

[0027] The wafer conveyance system 107 conveys and sets the semiconductor wafer 110 contained by the cassette which is not illustrated to the wafer stage 101.

[0028] The control operation part 108 performs drive control of the wafer conveyance system 107 while it performs position control of the wafer stage 101, the light source section 102, a scintillation counter 103, a substage condenser 104, and an electric eye 105, drive control, etc. and measures the property of the semiconductor wafer 110 (after-mentioned). Furthermore, measurement data is generated based on the signal inputted from the electric eye 105 and the spectroscope.

[0029] Next, the procedure of the evaluation method concerning this operation gestalt is explained. Drawing 2 is a flow chart which shows this procedure roughly.

[0030] ** Grow a thin film epitaxially to all the semiconductor wafers 110 of the same batch first (S201). The cross section of the

diaphragm structure of the semiconductor wafer 110 used for drawing 3 with this operation gestalt is shown. As mentioned above, this semiconductor wafer 110 is used for manufacture of the transistor for RFs. As shown in this drawing, with this operation gestalt, the half-insulation GaAs substrate 301 with a thickness of 600 micrometers is used as a semiconductor wafer 110. And in the front face of this GaAs substrate 301, it is [the non dope GaAs layer 302 of 500nm of thickness, the non dope InGaAs layer 303 (the composition ratio of In is about 0.15) of 10nm of thickness, and] 3.3x10¹⁸ high impurity concentration/cm in 40nm of thickness. It is [the AlGaAs layer 304 (the composition ratio of aluminum is about 0.2), and] 3.5x10¹⁸ high impurity concentration/cm in 50nm of thickness. The laminating of the GaAs

[0031] By the evaluation method concerning this operation gestalt, about all the semiconductor wafers 110 in which the thin film was formed, the following evaluations are performed and it differs from the conventional evaluation method mentioned above at this point. This is because the evaluation method concerning this operation gestalt has realized nondestructive inspection.

[0032] ** Next, set to the wafer stage 101 the semiconductor wafer 110 evaluated first, and perform cage hula doubling (S202). This setting can be automatically performed using the robot (not shown) of the wafer conveyance system 107.

[0033] ** Then, double the parallelism of the semiconductor wafer 110 set to the wafer stage 101 (S203). The Z-axis and theta shaft are adjusted in this alignment, irradiating an X-ray in parallel from X line source of the light source section 102 at the semiconductor wafer 110, and carrying out the monitor of the intensity of the reflective X-ray at this time by the scintillation counter 103. By this adjustment, an error can obtain the parallelism of less than 0.001 degrees.

[0034] ** And perform X-ray fluorescence as inspection of the beginning of the thin film formed in the semiconductor wafer 110 (S204). As mentioned above, at this X-ray fluorescence, an X-ray is irradiated from X line source of the light source section 102 on the thin film front face of the semiconductor wafer 110, and the fluorescence X rays generated in a thin film at this time are received by the electric eye 105. Thereby, drawing 4 which can know the pollutant in a thin film is a graph which shows the property acquired by doing in this way. In this drawing, a vertical axis shows the relative intensity [cps] of fluorescence X rays, and the horizontal axis shows energy [keV]. As shown in this drawing, P, Fe, and Zn are contained in the semiconductor wafer 110 used for this operation gestalt as a pollutant.

[0035] ** Next, measure a rocking curve as the second inspection of a thin film (S205). In this measurement, an X-ray is irradiated on the thin film front face of the semiconductor wafer 110 from X line source, making it move at the angle with which it is [X line source and the scintillation counter 103 of the light source section 102] satisfied of Bragg's principle. And the intensity of the diffraction X-ray at this time is measured by the scintillation counter 103. With this rocking curve, the composition ratio of In in the InGaAs layer 303 (refer to drawing 3) can be known.

[0036] Drawing 5 is a graph which shows the property acquired by doing in this way. In this drawing, a vertical axis shows the relative intensity [cps] of fluorescence X rays, and the horizontal axis shows the angle [a second].

[0037] ** Simultaneously with measurement (above-mentioned process **) of a rocking curve, also perform PL measurement as the third inspection of a thin film with this operation form (S205). In this measurement, a laser beam is irradiated from the argon laser of the light source section 102 at the semiconductor wafer 110, and the light by the photograph luminescence at this time is condensed with a substage condenser 104. The spectrum of the condensed light is sent and carried out to a spectroscope 106 by the optical fiber as mentioned above, it is changed by the photo multiplier in this spectroscope 106, and is sent to the control operation part 108. And the wavelength distribution of condensing intensity is computed by the control operation part 108. By the result of this PL measurement, the luminescence wavelength when manufacturing semiconductor laser from the semiconductor wafer 110 concerned can be known.

[0038] Drawing 6 is a graph which shows the property acquired by doing in this way. In this drawing, a vertical axis shows the relative intensity of photoluminescence light, and the horizontal axis shows the wavelength [nm] of photoluminescence light. Thereby, it turns out that luminescence from the quantum well which consists of InGaAs is near 965nm.

[0039] ** Then, observe the scattered light as the fourth inspection of a thin film (S206). In this observation, the laser beam which extracted the beam diameter to 1 micrometer is irradiated from the YAG laser of the light source section 102 at the semiconductor wafer 110. And the scattered light at this time is condensed with a substage condenser 104. Other angles are sufficient although the degree of illuminating angle of a laser beam may be the same as that of the case (above-mentioned process **) of PL measurement at this time. Moreover, it is also possible by scanning the wafer stage 101 on a X-Y side to take the mapping image of the scattered light.

[0040] By extracting a laser beam to about 1 micrometer, a laser beam enters in a thin film, a defective part is reached, and dispersion intensity increases. Moreover, it becomes possible by mapping to measure the distribution of the defect in a thin film.

[0041] Drawing 7 is the conceptual diagram showing the defective distribution obtained by doing in this way. In this drawing, (a) is the case where the degree of incident angle of a laser beam is 15.1 degrees, and (b) is the case where this degree of incident angle is 0.2 degrees.

[0042] With this operation gestalt, since the angle of a semiconductor wafer is set up through an X-ray (above-mentioned process **), the repeatability of the degree of illuminating angle of a laser beam can be raised, and, for this reason, low angle incidence becomes easy. Moreover, since the precision of angular dependence becomes strict, it becomes possible to get to know the distribution of a defect to the depth direction of a thin film, and, for this reason, only the defect in a thin film can be measured. In the GaAs substrate 301 (refer to drawing 3), it is 104. Since the about two cm [an individual / cm] crystal defect is contained, it is very important to separate and evaluate the defect in a substrate and the defect in a thin film.

[0043] ** Evaluate the quality of the thin film quality of the semiconductor wafer 110 of the batch concerned after that based on the result of each of these properties (S204 - S206 reference) (S207). The result of each above-mentioned property is examined separately, and this quality evaluation does not judge it, but associates these properties mutually and judges them. For example, even if the evaluation by a part of inspection is a "defect", when other inspection results are very good, it may make final quality evaluation "good."

[0044] Moreover, when required, the parameter of an epitaxial growth system is changed according to the result of each property.

[0045] Then, only the semiconductor wafer 110 which cleared such quality evaluation is thrown into the following manufacturing process (S208). And if the semiconductor device (here transistor for RFs) using this semiconductor wafer 110 is completed, the quality of this semiconductor device will be evaluated and final good/defect will be determined (S208).

[0046] ** At the end, change the error criterion of the semiconductor wafer 110 for the quality evaluation result of the completed equipment if needed as compared with the evaluation result of each property of the semiconductor wafer 110 (S209). Moreover, if required, the parameter of an epitaxial growth system will also be changed according to change of this error criterion. Thus, the relation between each property and the error criterion of a quality is experientially determined by comparing with the final good of a semiconductor device / poor judgment result which produced the measurement result of each above-mentioned property from the semiconductor wafer 101

concerned.

[0047] An example of transition of the yield of a final semiconductor device (here transistor for RF's) at the time of using this operation gestalt for drawing 8, and evaluating the semiconductor wafer 110 is shown. In this drawing, a vertical axis is a yield (%) and a horizontal axis is a lot number. Moreover, a white round head is the case where the evaluation method of this operation gestalt is used, and a black dot is the case where the conventional evaluation method (refer to drawing 9) is used.

[0048] As shown in this drawing, according to this operation gestalt, the yield of a semiconductor device was able to be reduced 30% on the average, and dispersion in the yield for every lot was also able to be suppressed further. This is because this operation gestalt has realized nondestructive inspection. That is, according to this operation gestalt, when the defective of a semiconductor device occurs in a subsequent manufacturing process, based on the own measurement result of a semiconductor wafer used for manufacture of the defective, the mutual relevance of each property is analyzable, and it is as a result of [of other semiconductor wafers 110 of the same batch] measurement, and it is not necessary to substitute. For this reason, since the mutual relevance about each property is strictly analyzable, the accuracy of the error criterion to the film quality of a semiconductor substrate can be increased, and, thereby, the reliability of evaluation can be raised.

[0049] Furthermore, according to this operation gestalt, since once is sufficient as the transfer of a semiconductor substrate, or a setup of an evaluation position, the duration of an evaluation process can also be shortened.

[0050]

[Effect of the Invention] It is effective, when reducing the manufacturing cost of a semiconductor device, since according to this invention the evaluation method of a reliable semiconductor substrate can be offered and improvement in the yield of a semiconductor device and shortening of evaluation time can be aimed at by this, as explained to the detail above.

[Translation done.]

* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

TECHNICAL FIELD

[The technical field to which invention belongs] this invention relates to the equipment and the method for carrying out non-destructing evaluation of the thickness of the thin film formed on the semiconductor substrate, composition, a luminescence property, the crystal defect, etc. at a detail more about the evaluation equipment and the evaluation method of a semiconductor substrate.

[Translation done.]

* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

PRIOR ART

[Description of the Prior Art] About an example of the evaluation method of the conventional semiconductor substrate, the case where the thin film grown epitaxially on the semiconductor substrate is evaluated is taken and explained to an example.

[0003] It is common to carry out the laminating of the dozens of layers super-thin film of 10nm of numbers from several nm in thickness by epitaxial growth with a heterojunction compound semiconductor epitaxial wafer with highly-efficient-izing of a device etc. In such a thin film, it is difficult to maintain the thickness of each class, composition, the concentration of doping, the steep nature of an interface, etc. with sufficient repeatability, and many properties of a thin film will be changed for every growth batch. For this reason, in a semiconductor manufacturing technology, after forming a thin film in a semiconductor substrate, while establishing a thin film evaluation process and sorting out the good/defect of a semiconductor substrate, it is necessary to correct the parameter of thin film deposition systems (MBE: equipment or MOCVD system).

[0004] Drawing 2 is a flow chart which shows the procedure of the conventional evaluation method roughly.

[0005] As shown in drawing 2, by the conventional evaluation method, first, a thin film is grown epitaxially to all the semiconductor wafers of the same batch (S901), then the semiconductor wafer for evaluation is sorted out from these semiconductor wafers (S902). And the following evaluation examinations are performed one by one about the semiconductor wafer sorted out.

[0006] And this semiconductor wafer is set in film quality evaluation equipment, and film quality of an epitaxial growth phase is inspected (S903). In this film quality, after setting a semiconductor wafer to the wafer stage of an oblique light illumination unit, counting of the number of the particle of the whole semiconductor wafer surface is carried out using the surface contamination test equipment and the optical microscope which are called a particle counter.

[0007] Next, this semiconductor wafer is conveyed, it sets to the wafer stage of X diffraction equipment, and the rocking curve of an epitaxial growth phase is measured about arbitrary setting positions (S904). In this measurement, an X-ray is irradiated from X line source at an epitaxial growth phase, and the optical intensity of the diffracted light is measured by the scintillation counter. Thereby, composition of an epitaxial growth phase, thickness, etc. can be specified.

[0008] Then, this semiconductor wafer is conveyed, it sets to the wafer stage of PL (Photo Luminescence) evaluation equipment, and the luminescence intensity of photograph luminescence is measured about arbitrary setting positions (S905). According to measurement of this luminescence intensity, the luminescence wavelength of the semiconductor laser manufactured using this semiconductor wafer can be specified.

[0009] Then, based on the result of each of these properties (S903-S905), the quality of the thin film quality of the semiconductor wafer of the batch concerned is judged (S906). As for this quality evaluation, according to this invention person's etc. examination, it is desirable to examine the result of each above-mentioned property separately, not to judge it, but to associate these properties mutually and to judge them. For example, even if the property (namely, number of particle) measured with the oblique light illumination unit was a "defect", when the property measured with X diffraction equipment or PL evaluation equipment is very good, it may make quality evaluation "good." It is because the yield is made to fall more than required and it becomes the cause of manufacturing-cost elevation, when any one kind of the inspection item becomes a "defect" and it always judges quality evaluation to be a "defect." Here, the mutual relevance of each property changes with the kind of semiconductor device produced using the semiconductor wafer concerned, degrees of integration, uses, etc., and is experientially determined by comparing the measurement result of each above-mentioned property with the final good of a semiconductor device / poor judgment result etc.

[0010] And only when such quality evaluation is cleared, other semiconductor wafers of the batch concerned are thrown into the following manufacturing process.

[Translation done.]

• NOTICES •

Japan Patent Office is not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

EFFECT OF THE INVENTION

[Effect of the Invention] It is effective, when reducing the manufacturing cost of a semiconductor device, since according to this invention the evaluation method of a reliable semiconductor substrate can be offered and improvement in the yield of a semiconductor device and shortening of evaluation time can be aimed at by this, as explained to the detail above.

[Translation done.]

* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

 TECHNICAL PROBLEM

{Problem(s) to be Solved by the Invention} As mentioned above, it is common that the film quality evaluation of a semiconductor wafer estimates based on the measurement result about two or more kinds of properties. Thus, since different evaluation equipment for every parameter was conventionally used when two or more kinds of measurement was performed, the semiconductor wafer had to be transported for every measurement and it had to set to the wafer stage. For example, in the case of the evaluation method shown in drawing 9, it will be necessary to transport a semiconductor wafer in order of oblique light illumination unit -> X diffraction equipment -> PL evaluation equipment. For this reason, in the conventional evaluation method, in order to conduct inspection of two or more items about the same part of a semiconductor wafer front face, marking of the evaluation part of a semiconductor wafer needed to be carried out with the felt-tipped marker etc.

[0012] however, since marking by this felt-tipped marker etc. makes a semiconductor wafer pollute, and it is not nondestructive inspection namely, it cannot throw into a subsequent manufacturing process the semiconductor wafer by which marking was carried out. That is, by the conventional method, only the semiconductor wafer which did not pass through the above evaluation processes is thrown into a subsequent manufacturing process. For this reason, when the defective of a semiconductor device occurs in a subsequent manufacturing process, the measurement result about the property of the semiconductor wafer used for manufacture of the defective is not left behind.

[0013] On the other hand, in not performing marking, problems, like there is no repeatability in the precision of the position which evaluates arise.

[0014] Therefore, by the conventional evaluation method, it considered that the measurement result about the semiconductor wafer of the same batch as the semiconductor device judged to be a defective is the property of the semiconductor wafer used for manufacture of this defective, and was used for the analysis of the mutual relevance of each property. For this reason, mutual relevance about each property could not be analyzed strictly, and the reliability of the evaluation to the film quality of a semiconductor wafer was low.

[0015] Thus, a low case, since the semiconductor wafer which can be thrown into a manufacturing process may originally not only be judged to be a "defect", but the semiconductor wafer which should be made into a "defect" will originally be thrown into a manufacturing process, the reliability of the evaluation to the film quality of a semiconductor wafer also causes the fall of the yield in final evaluation of a semiconductor device. Therefore, in a low case, the reliability of the evaluation to film quality will become [the manufacturing cost of a semiconductor device] very large.

[0016] Moreover, since a transfer of a semiconductor wafer and a setup of an evaluation position would take a long time when transporting a semiconductor wafer for every measurement and setting to a wafer stage like the evaluation method shown in drawing 9, there was also a fault that the duration of an evaluation process will become long.

[0017] this invention is made in view of the fault of such conventional technology, and aims at offering the evaluation method of a reliable semiconductor substrate.

[Translation done.]

* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

MEANS

[Means for Solving the Problem] Substrate maintenance process in which the position and angle of the aforementioned semiconductor substrate which were laid in this installation base are adjusted by the controller after laying the semiconductor substrate for the evaluation method of the semiconductor substrate concerning this invention evaluating in an installation base. Two or more kinds of evaluation light used for two or more kinds of evaluations is irradiated sequential or simultaneous through the same optical path at the aforementioned semiconductor substrate on the aforementioned installation base from two or more kinds of light sources. By detecting the reflected light or the fluorescence at this time by two or more kinds of light sensitive cells, respectively Two or more aforementioned kinds of properties measured in the inspection process which measures two or more kinds of properties of the aforementioned semiconductor substrate, and this inspection process By comparing with the final good to the semiconductor device produced from the aforementioned semiconductor substrate which passed through this inspection process / poor judgment result, it is characterized by having the error-criterion decision process which determines or changes the error criterion of the aforementioned semiconductor substrate.

[0019]

[Embodiments of the Invention] Hereafter, 1 operation gestalt of this invention is explained taking the case of the case where the semiconductor wafer used for manufacture of the transistor for RFs is evaluated.

[0020] Drawing 1 is the conceptual diagram showing the composition of the evaluation equipment used for this operation gestalt.

[0021] In this drawing, the wafer stage 101 holds the semiconductor wafer 110. The drive of movement to the direction of X, the direction of Y, and a Z direction, theta rotation, and phi rotation is possible for this wafer stage 101. Here, movement to the direction of X, the direction of Y, and a Z direction is controllable by the 1-micrometer step. Moreover, theta rotation can control phi rotation by the pitch of 0.001 degrees 0.0001 degrees.

[0022] The light source section 102 is equipped with copper or X line source (either an enclosure pipe or a rotating target is OK) of molybdenum, the argon laser (luminescence wavelength of 488nm), and the YAG laser (luminescence wavelength of 1.06 micrometers) (neither is illustrated). Furthermore, this light source section 102 is equipped with the mirror and analysing crystal (neither is illustrated) for drawing the evaluation light (namely, an X-ray and a laser beam) irradiated from each of these light sources on the same optical axis. Moreover, each light source of the light source section 102 can make the periphery top which makes the wafer stage 101 the center of rotation drive at the step of 0.0001 angle errors by control of the control operation part 108.

[0023] A scintillation counter 103 is used in order to receive the X-ray which irradiated from X line source of the light source section 102, and was reflected on semiconductor wafer 110 front face and to measure optical intensity. This scintillation counter 103 can make the periphery top which makes the wafer stage 101 the center of rotation drive at the step of 0.0001 angle errors by control of the control operation part 108 like the light source of the light source section 102.

[0024] The substage condenser 104 is arranged right above the wafer stage 101. Since luminescence of the photograph luminescence when irradiating the argon laser light of the light source section 102 is condensed to the semiconductor wafer 110 on the wafer stage 101, and since the scattered light when irradiating the YAG-laser light of the light source section 102 is condensed, this substage condenser 104 is used.

[0025] The electric eye 105 as well as a substage condenser 104 is arranged right above the wafer stage 101. This electric eye 105 exchanges a position for a substage condenser 104 mutually, and it is held by the drive system which is not illustrated so that it can move onto the core of the semiconductor wafer 110 on the wafer stage 101. Moreover, SSD (Solid State Detector) which is the detector of fluorescence X rays as this electric eye 105 is used, and the fluorescence X rays generated when an X-ray is irradiated at the semiconductor wafer 110 on the wafer stage 101 are received.

[0026] The spectroscope 106 is connected with the output terminal of a substage condenser 104 by the optical fiber. And the wavelength distribution of condensing intensity is measured using the lightwave signal inputted from the substage condenser 104. The measured wavelength distribution is outputted from the signal output terminal (not shown) of a spectroscope 106.

[0027] The wafer conveyance system 107 conveys and sets the semiconductor wafer 110 contained by the cassette which is not illustrated to the wafer stage 101.

[0028] The control operation part 108 performs drive control of the wafer conveyance system 107 while it performs position control of the wafer stage 101, the light source section 102, a scintillation counter 103, a substage condenser 104, and an electric eye 105, drive control, etc. and measures the property of the semiconductor wafer 110 (after-mentioned). Furthermore, measurement data is generated based on the signal inputted from the electric eye 105 and the spectroscope 106.

[0029] Next, the procedure of the evaluation method concerning this operation gestalt is explained. Drawine 2 is a flow chart which shows this procedure roughly.

[0030] ** Grow a thin film epitaxially to all the semiconductor wafers 110 of the same batch first (S201). The cross section of the diaphragm structure of the semiconductor wafer 110 used for drawing 3 with this operation gestalt is shown. As mentioned above, this semiconductor wafer 110 is used for manufacture of the transistor for RFs. As shown in this drawing, with this operation gestalt, the half-insulation GaAs substrate 301 with a thickness of 600 micrometers is used as a semiconductor wafer 110. And in the front face of this GaAs substrate 301, it is [the non dope GaAs layer 302 of 500nm of thickness, the non dope InGaAs layer 303 (the composition ratio of In is about 0.15) of 10nm of thickness, and] 3 3x10¹⁸ high impurity concentration/cm in 40nm of thickness. It is [the AlGaAs layer 304 (the composition ratio of aluminum is about 0.2), and] 3 5x10¹⁸ high impurity concentration/cm in 50nm of thickness. The laminating of the

GaAs

[0031] By the evaluation method concerning this operation gestalt, about all the semiconductor wafers 110 in which the thin film was formed, the following evaluations are performed and it differs from the conventional evaluation method mentioned above at this point. This is because the evaluation method concerning this operation gestalt has realized nondestructive inspection.

[0032] ** Next, set to the wafer stage 101 the semiconductor wafer 110 evaluated first, and perform cage hula doubling (S202). This setting can be automatically performed using the robot (not shown) of the wafer conveyance system 107.

[0033] ** Then, double the parallelism of the semiconductor wafer 110 set to the wafer stage 101 (S203). The Z-axis and theta shaft are adjusted in this alignment, irradiating an X-ray in parallel from X line source of the light source section 102 at the semiconductor wafer 110, and carrying out the monitor of the intensity of the reflective X-ray at this time by the scintillation counter 103. By this adjustment, an error can obtain the parallelism of less than 0.001 degrees.

[0034] ** And perform X-ray fluorescence as inspection of the beginning of the thin film formed in the semiconductor wafer 110 (S204). As mentioned above, at this X-ray fluorescence, an X-ray is irradiated from X line source of the light source section 102 on the thin film front face of the semiconductor wafer 110, and the fluorescence X rays generated in a thin film at this time are received by the electric eye 105. Thereby, drawing 4, which can know the pollutant in a thin film is a graph which shows the property acquired by doing in this way. In this drawing, a vertical axis shows the relative intensity (cps) of fluorescence X rays, and the horizontal axis shows energy [keV]. As shown in this drawing, P, Fe, and Zn are contained in the semiconductor wafer 110 used for this operation gestalt as a pollutant.

[0035] ** Next, measure a rocking curve as the second inspection of a thin film (S205). In this measurement, an X-ray is irradiated on the thin film front face of the semiconductor wafer 110 from X line source, making it move at the angle with which it is [X line source and the scintillation counter 103 of the light source section 102] satisfied of Bragg's principle. And the intensity of the diffraction X-ray at this time is measured by the scintillation counter 103. With this rocking curve, the composition ratio of In in the InGaAs layer 303 (refer to drawing 3) can be known.

[0036] Drawing 5 is a graph which shows the property acquired by doing in this way. In this drawing, a vertical axis shows the relative intensity (cps) of fluorescence X rays, and the horizontal axis shows the angle [a second].

[0037] ** Simultaneously with measurement (above-mentioned process **) of a rocking curve, also perform PL measurement as the third inspection of a thin film with this operation gestalt (S205). In this measurement, a laser beam is irradiated from the argon laser of the light source section 102 at the semiconductor wafer 110, and the light by the photoluminescence at this time is condensed with a substage condenser 104. The spectrum of the condensed light is sent and carried out to a spectroscope 106 by the optical fiber as mentioned above, it is changed by the photo multiplier in this spectroscope 106, and is sent to the control operation part 108. And the wavelength distribution of condensing intensity is computed by the control operation part 108. By the result of this PL measurement, the luminescence wavelength when manufacturing semiconductor laser from the semiconductor wafer 110 concerned can be known.

[0038] Drawing 6 is a graph which shows the property acquired by doing in this way. In this drawing, a vertical axis shows the relative intensity of photoluminescence light, and the horizontal axis shows the wavelength [nm] of photoluminescence light. Thereby, it turns out that luminescence from the quantum well which consists of InGaAs is near 965nm.

[0039] ** Then, observe the scattered light as the fourth inspection of a thin film (S206). In this observation, the laser beam, which extracted the beam diameter to 1 micrometer is irradiated from the YAG laser of the light source section 102 at the semiconductor wafer 110. And the scattered light at this time is condensed with a substage condenser 104. Other angles are sufficient although the degree of illuminating angle of a laser beam may be the same as that of the case (above-mentioned process **) of PL measurement at this time. Moreover, it is also possible by scanning the wafer stage 101 on a X-Y side to take the mapping image of the scattered light.

[0040] By extracting a laser beam to about 1 micrometer, a laser beam enters in a thin film, a defective part is reached, and dispersion intensity increases. Moreover, it becomes possible by mapping to measure the distribution of the defect in a thin film.

[0041] Drawing 7 is the conceptual diagram showing the defective distribution obtained by doing in this way. In this drawing, (a) is the case where the degree of incident angle of a laser beam is 15.1 degrees, and (b) is the case where this degree of incident angle is 0.2 degrees.

[0042] With this operation gestalt, since the angle of a semiconductor wafer is set up through an X-ray (above-mentioned process **), the repeatability of the degree of illuminating angle of a laser beam can be raised, and, for this reason, low angle incidence becomes easy. Moreover, since the precision of angular dependence becomes strict, it becomes possible to get to know the distribution of a defect to the depth direction of a thin film, and, for this reason, only the defect in a thin film can be measured. In the GaAs substrate 301 (refer to drawing 3), it is 104. Since the about two cm [an individual / cm] crystal defect is contained, it is very important to separate and evaluate the defect in a substrate and the defect in a thin film.

[0043] ** Evaluate the quality of the thin film quality of the semiconductor wafer 110 of the batch concerned after that based on the result of each of these properties (S204 - S206 reference) (S207). The result of each above-mentioned property is examined separately, and this quality evaluation does not judge it, but associates these properties mutually and judges them. For example, even if the evaluation by a part of inspection is a "defect", when other inspection results are very good, it may make final quality evaluation "good."

[0044] Moreover, when required, the parameter of an epitaxial growth system is changed according to the result of each property.

[0045] Then, only the semiconductor wafer 110 which cleared such quality evaluation is thrown into the following manufacturing process (S208). And if the semiconductor device (here transistor for RFs) using this semiconductor wafer 110 is completed, the quality of this semiconductor device will be evaluated and final good/defect will be determined (S208).

[0046] ** At the end, change the error criterion of the semiconductor wafer 110 for the quality evaluation result of the completed equipment if needed as compared with the evaluation result of each property of the semiconductor wafer 110 (S209). Moreover, if required, the parameter of an epitaxial growth system will also be changed according to change of this error criterion. Thus, the relation between each property and the error criterion of a quality is experientially determined by comparing with the final good of a semiconductor device / poor judgment result which produced the measurement result of each above-mentioned property from the semiconductor wafer 101 concerned.

[0047] An example of transition of the yield of a final semiconductor device (here transistor for RFs) at the time of using this operation gestalt for drawing 8, and evaluating the semiconductor wafer 110 is shown. In this drawing, a vertical axis is a yield (%) and a horizontal axis is a lot number. Moreover, a white round head is the case where the evaluation method of this operation gestalt is used, and a black dot is the case where the conventional evaluation method (refer to drawing 9) is used.

[0048] As shown in this drawing, according to this operation gestalt, the yield of a semiconductor device was able to be reduced 30% on

the average, and dispersion in the yield for every lot was also able to be suppressed further. This is because this operation gestalt has realized nondestructive inspection. That is, according to this operation gestalt, when the defective of a semiconductor device occurs in a subsequent manufacturing process, based on the own measurement result of a semiconductor wafer used for manufacture of the defective, the mutual relevance of each property is analyzable, and it is as a result of [of other semiconductor wafers 110 of the same batch] measurement, and it is not necessary to substitute. For this reason, since the mutual relevance about each property is strictly analyzable, the accuracy of the error criterion to the film quality of a semiconductor substrate can be increased, and, thereby, the reliability of evaluation can be raised.

[0049] Furthermore, according to this operation gestalt, since once is sufficient as the transfer of a semiconductor substrate, or a setup of an evaluation position, the duration of an evaluation process can also be shortened.

[Translation done.]

* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

1. This document has been translated by computer. So the translation may not reflect the original precisely.
2. **** shows the word which can not be translated.
3. In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the conceptual diagram showing the composition of the evaluation equipment used for 1 operation gestalt of this invention.

[Drawing 2] It is the flow chart which shows the procedure of the evaluation method concerning 1 operation gestalt of this invention.

[Drawing 3] It is the cross section showing the diaphragm structure of the semiconductor substrate used with 1 operation gestalt of this invention.

[Drawing 4] It is the graph which shows the X-ray fluorescence result obtained by the evaluation method concerning 1 operation gestalt of this invention.

[Drawing 5] It is the graph which shows the rocking curve obtained by the evaluation method concerning 1 operation gestalt of this invention.

[Drawing 6] It is the graph which shows the measurement result of the photoluminescence obtained by the evaluation method concerning 1 operation gestalt of this invention.

[Drawing 7] It is drawing showing notionally the defective distribution obtained by the evaluation method concerning 1 operation gestalt of this invention, and, for (a), this degree of incident angle is the case where (b) is 0.2 degrees when the degree of incident angle of a laser beam is 15.1 degrees.

[Drawing 8] It is the graph which shows an example of transition of the yield of a final semiconductor device at the time of performing the evaluation method concerning 1 operation gestalt of this invention.

[Drawing 9] It is the flow chart which shows the procedure of the conventional evaluation method roughly.

[Description of Notations]

101 Wafer Stage

102 Light Source

103 Scintillation Counter

104 Substage Condenser

105 Electric Eye

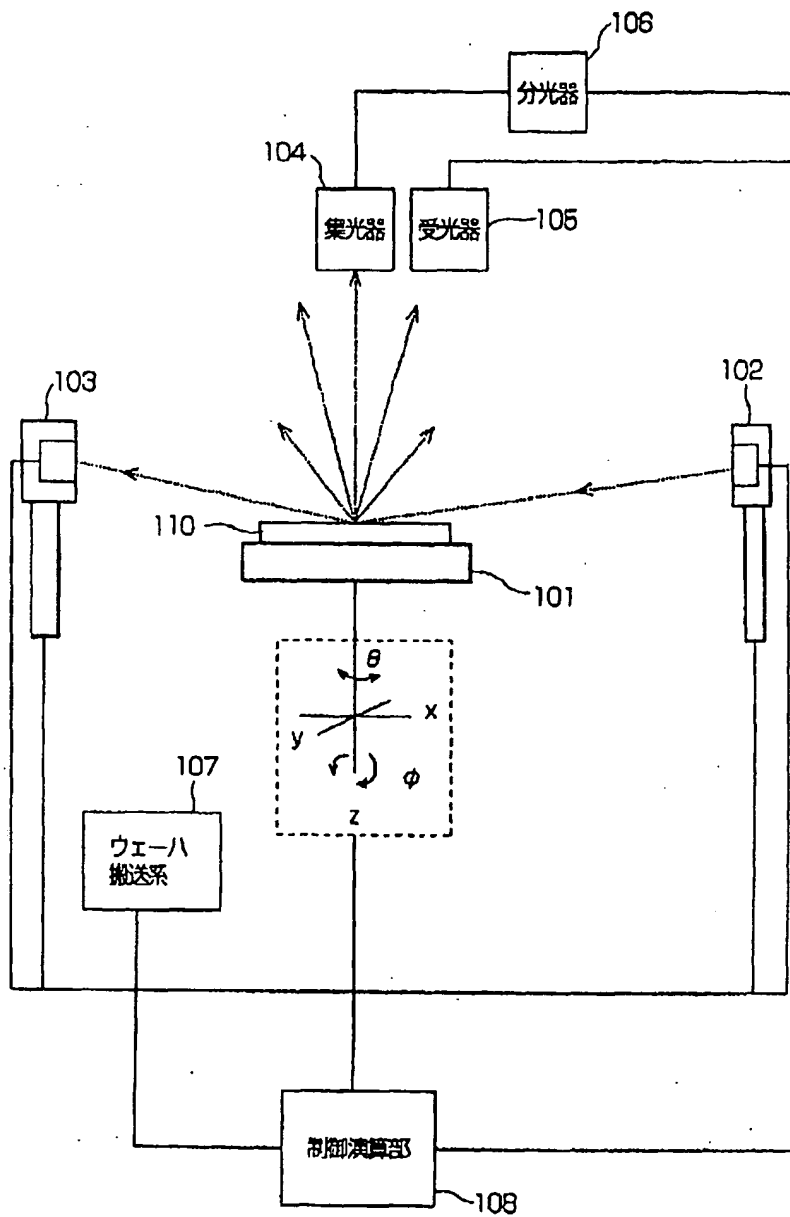
106 Spectroscope

107 Wafer Conveyance System

108 Control Operation Part

110 Semiconductor Wafer

[Translation done.]

Drawing selection **drawing 1**

[Translation done.]

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☒ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.